CHAPTER 8

QUALITY CONTROL AND QUALITY ASSURANCE

8-1. General.

a. Quality control and quality assurance are defined and explained generally in ER 1180-1-6 and EM 1110-2-1910. In the context of construction with large stone, it is useful to distinguish within the program of contractor quality control the responsibility for material suitability as well as the broad responsibility for satisfactory construction procedures and results. The following guidance is organized with this distinction in mind. The quality assurance program of the CE tracks similarly in its role of monitoring quality control and achieving the specified engineered structure.

b. Satisfactory construction is realized by adherence to the requirements of structural or hydraulic design. Toward this objective, plans and specifications establish requirements of stone material and construction from among several key factors.

(1) Source, including specific stratum.

(2) Size and gradation and limiting percentage of undesirable materials.

(3) Shape limit, as a ratio of length and thickness.

(4) Stone quality characteristics.

(5) Engineering design such as unit weight, layer thickness, and tolerance as well as (2) above.

(6) Placement limitations such as not dropping stones.

(7) Packing, also expressed as keying.

(8) Quarry limitations such as blasting patterns and choice of blasting agent. Such restrictions are seldom used.

(9) Test methods, including frequency.

8-2. Contractor Quality Control. Contractor quality control (CQC) refers to the contractor's own system for managing quality of construction activities as well as activities of suppliers and subcontractors. A daily report is usually required to summarize CQC.

a. Specifications.

(1) The contract documents normally establish the minimum level of quality and control required in a project to be constructed. Specifications must clearly define the quality of materials and workmanship required. The construction contractor must comply with the contract documents and produce the required end product.

(2) As explained in ER 1180-1-6, provisions for CQC are required in all construction contracts. In contracts exceeding $1,000,000, detailed CQC is needed and a special clause entitled "Contractor Quality Control" is included. Application of detailed CQC to construction contracts under $1,000,000, such as limited riprap repair, is discretionary, and the contract clause entitled "Inspection of Construction" may be used instead.

b. Material Control.

(1) Preparations.

(a) Prior to stone production, the contractor explains in writing for CE approval the details of testing methods and observations to be followed. Details should include size, weight, processing, and handling of the sample. All CQC tests are performed by and at the expense of the contractor. Samples for testing should be selected by the contractor with the concurrence of the contracting officer’s representatives. Tests should be made as specified in the contract, and any adjustment to the contractor’s operation necessary to provide stone meeting contract requirements should be at the contractor’s expense.

(b) The contractor’s quarry inspector and the contracting officer’s representative should meet at each quarry designated to supply stone before delivery of stone to the job. At this time they select representative large stones for set-aside at the quarry as reference samples (paragraph 6-3d). Both satisfactory and unsatisfactory reference stones should be clearly identified. The defects in unsatisfactory stone should be marked. These typical samples often remain useful to CQC through completion of the project. All stone types need to be set aside. Samples should consist of at least one stone representing each size class in the gradation range.

(2) Testing.

(a) Stone produced during start-up operations at the quarry should be scrutinized for quality, unit weight, and gradation to indicate quarry or supplier capability for meeting specifications. Typically, three consecutive samples should pass all requirements, witnessed by the contracting officer’s representative, prior to full operation and shipments to the project. The basic tests are visual examination, index tests, drop test, and size counts and any other tests required by the contract.

(b) Stone quality is tested at the quarry or jobsite regularly throughout construction; alternating between quarry and jobsite may be preferred. Tentative acceptance of stone is sometimes made based on the test results. Tests producing unacceptable results should not be counted in the required number. Samples for production testing should be taken from materials as they are produced or handled. A format for a schedule of tests at a large dike project is given in Table 8-1. The number of tests is based on experience in the particular region. Where the frequency of production testing needs to be increased to control the material quality, any additional expense is borne by the contractor.

Table 8-1. Format for Production Control Testing of Large Retention Dike Project

Number Stone	Stone Sizes	Type of Test	Minimum Size of Sample	Minimum of Tests
Armor or Underlayer		Visual exam		All stones
Armor or Underlayer	Over 500 lb	Measurement and weight	Truck load or equivalent weight per barge load	One for each _____ tons produced
Underlayer or Armor	500 lb and under	Measurement and weight	Truck load or equivalent weight per barge load	One for each _____ tons produced
Core or Mattress	All sizes	Gradation	1 ton	One for each _____ tons produced
Bedding Material	All sizes	Gradation	1 ton	One for each _____ tons produced

The minimum number and size of tests will vary with each project.

(c) Stones less than 500 lb are weighed and tabulated in a manner approved by the contracting officer for comparison with the specified gradation. Stones over 500 lb should be measured on three mutually perpendicular axes. Measurements and computed weights are all recorded along with a description of methods of weighing and calculating. Stones over 500 lb are weighed on scales as necessary to verify questionable computed weights. Stone selected for measurement should represent all sizes specified in order to verify conformance with the specified weight limits. The contractor is normally required to supply scales and certification of their accuracy.

(3) Visual Inspections. Visual checks of all stone are frequently required at the quarry or at the project for size, gradation, and slabbiness, as well as for cracks and other weaknesses visible on the stone surfaces. Wetting a small representative portion of stones may accentuate minute cracks and reveal if additional inspections are necessary on all stone. Stone with cracks and other defects that are not in accordance with the specifications should not be shipped to the project site. Photographs are useful in documenting quality.

c. Placement Control. Stone placed but then found to be damaged, deficient in weight, or improperly placed must be removed and replaced with new stone or be corrected. The contractor has a vested interest in carefully

controlling the handling and placement of stone at the jobsite. This control is summarized in the daily CQC report to the Government.

(1) Visual Inspection. All stone should be visually inspected under CQC for size, gradation, and fractures to assure that handling during loading, transporting, unloading, and placement has not caused degradation and to assure that stone meets the requirements of the specifications. Close visual inspection after placement reveals the degree of uniform distribution of different sizes and close-knit arrangement among individual pieces as well as deficiencies such as large voids. Reworking is often necessary but can be minimized with care in ensuring that each arriving load has the proper gradation.

(2) In-Place Testing.

(a) In-place tests of stone material are made early in placement operations and should continue intermittently to confirm that the placement procedures and equipment are satisfactory. Satisfactory stone size and quality, layer thickness, and density in terms of void space and stone interlock underlie evaluation criteria. In-place tests should be located and witnessed by the contracting officer’s representative. Test failures ordinarily necessitate reworking or replacement. Work should not continue until the initial placement test results are acceptable to the contracting officer. Test areas are marked as guidance for all the remaining work.

(b) For riprap, EM 1110-2-1601 recommends that provisions be made in the specifications for testing an in-place sample as soon as a representative section has been completed, with additional testing of in-place and in-transit samples at the option of the contracting officer. The frequency of testing depends on the ease of producing riprap that complies with the specifications. Engineer Manual 1110-2-1911 suggests tests be made as frequently as each 10,000 cu yd placed. The size of test samples should be sufficient to be representative of the riprap. Truck-load samples are usually satisfactory for in-transit material. Table 8-2 summaries guidance from EM 1110-2-1601 for the volume of in-place samples. Results of gradation tests are reported on ENG Form 4055 or 4056 and appended to the CQC report.

Table 8-2. Suggested Sample Volumes for Riprap In-Place

Riprap Layer Thickness, in.	Sample Bulk Volume, cu yd
12	1
18	2
24	5
30	10
36	16

(c) Testing suited to construction of retention dikes may be established much as follows and should also be carefully explained in the contract. Each test area is about 10 by 10 ft for stones 500 lb and over and 5 by 5 ft for those under 500 lb. All stones within the area are removed, examined, and

measured or weighed individually on certified scales or otherwise as appropriate. For stone to be placed under water, only loose samples for gradation and weight are taken, just prior to placement.

d. Check Surveys.

(1) Check surveys are required in CQC on each layer to verify lines, grades, and thickness on completed work. The surveys are made as the work progresses. This paragraph emphasizes the rather elaborate methods needed in surveying large-volume jobs such as breakwaters. More expedient methods usually suffice for riprap features and rockfill embankments.

(2) Figure 8-1 shows technical provisions that have been used to describe the required surveying. Elevations of stone above the water surface or with respect to another datum should be determined with a leveling instrument and a rod on a base 12 in. in diameter. Other means approved by the contracting officer may be used. However, an electronic sounding method should not be used on riprap or larger stone material.

11.4 Check Surveys.

11.4.1 General. Surveys made by the Contractor will be required on each material placed for determining that the materials are acceptably placed in the work. The Contractor shall make checks as the work progresses to verify lines, grades, and thicknesses established on completed work. At least one (1) check survey as specified below shall be made by the Contractor for each 50-foot section as soon as practicable after completion. A copy of the record of the check survey shall be provided to the Contracting Officer on the next work day following the survey. Following placement of each type of material, the cross section of the finished work shall be approved by a representative of the Contracting Officer. Approval of cross sections shall not constitute final acceptance. Cross sections shall be taken by the Contractor on lines 50 feet apart, measured along the breakwater reference line, with readings at 10-foot intervals and at breaks along the lines. However, other cross section spacings and reading intervals may be used if determined appropriate by the Contracting Officer. Additional elevations and soundings shall also be taken as the Contracting Officer deems necessary or advisable. The surveys shall be conducted in the presence of a representative of the Contracting Officer, unless waived by the Contracting Officer.

Figure 8-1. Example technical provisions for check surveys. (Not intended for direct use; this example only illustrates how technical data are ultimately presented in contract language)

(3) Figure 8-2 shows technical provisions used to describe methods needed for surveys of material placed below water. Figure 8-3 shows by example the degree of control or standard under which the contractor might work in constructing and checking a major large-stone project.

11.4.3 Below Water. For portions of the work that are under water, sounding surveys shall be performed as specified below.

11.4.3.1 Lead line. If the lead-line method is used, each survey will consist of soundings taken either by means of a sounding pole or a sounding basket weighing about 8-1/2 pounds, each of which has a base measuring twelve (12) inches in diameter.

11.4.3.2 Electronic depth recorder method. When using an electronic depth recorder, the following procedures shall be used. The depth recorder will be calibrated and adjusted for the gauge, with check bar, at least six (6) times within a normal 8-hour work day. Normal calibration times shall be at the beginning of the work day, mid-morning, end of morning's work, start of afternoon's work, mid-afternoon, and end of the work day. Further calibrations will be taken whenever there is any malfunctions within the depth recorder or transducer which might affect the soundings, a major gauge change, or change in water temperature due to industrial discharge. The check bar will be set at approximately the deepest sounding in the area to be sounded. The depth recorder will be calibrated to read at low-morning, mid-afternoon and end of work day, the same settings used for the previous calibration will be used. If the calibration check does not agree with the previous calibration, the depth recorder will be calibrated to the proper setting. Under no circumstances shall the setting of the depth recorder be changed between calibrations.

11.4.3.3 Tagline method of horizontal location along station. If a tagline is used with a depth recorder, the soundings will be marked with a fix every five (5) feet.

11.4.3.4 Predetermined transit angle method or ranges method. The interval between predetermined angles or ranges along a sounding line shall not exceed 200 feet along the entire length of the sounding line. No predetermined angle shall form an intersection with the sounding of less than 45 degrees.

11.4.3.5 Speed of sounding boat. When sounding, the speed of the sounding boat shall be as constant as possible, preferably between 180 and 220 feet per minute.

11.4.3.6 Checking gauge. The gauge will be checked prior to each calibration and recorded on the sounding chart or in the field notes.

11.4.3.7 Electronic depth recorder. The survey depth recorder used must be a standard model acceptable to the Contracting Officer using a sounding chart that can be read directly to the nearest foot and estimated to the nearest tenth (0.1) of a foot. Accuracy shall be better than 1/2 of 1 percent.

Figure 8-2. Example technical provision for underwater check surveys. (Not intended for direct use; this example only illustrates how technical data are ultimately presented in contract language)

10.8 Tolerances. The finished surface and stone layer thickness shall not deviate from the lines and grades shown on the contract drawing by more than the tolerances listed on the table below. Tolerance thicknesses are measured perpendicular to the indicated neatlines. Extreme limits of the tolerances given on the table below shall not be continuous in any direction for more than five (5) times the average stone dimension and/or for an area greater than 1,000 square feet of the structure surface.

NEATLINE TOLERANCES

Material	Above Neatline (inches)	Below Neatline (inches)
Cover Stone, Type "A"	18	6
Underlayer, Type "B"	12	6
Underlayer, Type "C"	12	6
Bedding Material, Type "D"	12	0

NOTE; Add Mattress Stone, Core Stone, and Prepared Limestone if applicable.

The intention is that the work will be built generally to the required elevations, slope, and grade and that the outer surfaces shall be even and shall present a neat appearance. Placed material not meeting these limits shall be removed and/or reworked as directed by the Contracting Officer. Excess material permitted to remain in place the by Contracting Officer will not be paid for.

Figure 8-3. Example technical provisions on tolerances for a finished breakwater. (Not intended for direct use; this example only illustrates how technical data are ultimately presented in contract language)

e. Reporting. A written report should be prepared each day by the CQC detailing loads or weights of stone both delivered to the site and placed on the slope or structure. Results of visual examination are included, as well as sections surveyed. Samples taken for testing should be identified carefully for eventual correlation with test results developed subsequently. Engineer Form 4056 is useful for presenting stone size gradation. The report is to be furnished to the contracting officer in a timely manner and is preserved as an attachment to a daily QA report.

8-3. Quality Assurance. Quality assurance is performed by the Government in accordance with ER 1180-1-6. Checks, inspections, and tests are made of materials, methods, and the finished feature itself. The purpose is to determine whether the CQC is effective and is meeting the requirements of the contract. Personnel conducting the QA program should be proficient in large-stone inspection and familiar with quarry operations. Engineer Manual 1110-2-1911 contains guidance on rockfill construction control.

a. Inspection and Testing. Visual QA inspections of stone are performed both prior to and after delivery to the jobsite. In addition, physical sampling and testing such as used in CQC are conducted by the Government for QA at about one-tenth the frequency. The purpose is to confirm the validity of CQC results. If the contracting officer suspects that the quality, gradation, or weight of stone being furnished are not consistently as specified, supplemental sampling and testing by the contractor will be required. Selection of samples of the delivered stone and the manner in which the test is performed are as directed by the contracting officer. This additional sampling and testing is performed at the contractor's expense when test results indicate that the material does not meet specified requirements.

b. Reporting. Results of QA are reported daily on or appended to ENG Form 2538 as prescribed in ER 415-1-302 along with the CQC report.

c. Acceptance. The inspection or QA program should be carefully organized and conducted where questions of acceptance of stone material can enter prematurely and present a potential for problems. Acceptance usually needs to be postponed so that material and workmanship remain clearly subject to rejection until measurement for payment. Inspection by divers is sometimes needed to evaluate the acceptability of stone placed under water.

d. Rejection. The contracting officer reserves the right to reject at the source, at the job yard, or finally in the structure throughout the duration of the contract. Stone delivered to the project and then rejected, whether in stockpile or in place in the structure, should be removed from the project site. Stone found deficient at the quarry should be either isolated or disposed or otherwise prevented from mixing with satisfactory stone.

e. Retests. The Government should reserve the right to test or retest any of the stone used on the project at Government expense. A stone feature reworked or formed by replacement of previous, defective stone is to be tested as originally intended at the expense of the contractor.

8-4. Monitoring Stone Production. Although the commercial production of large stone is usually beyond the control of the Government, it is incumbent upon the CE to be aware of practices at the source affecting suitability of material to be delivered to the project. Forewarned in this way, the inspectors can be watchful for specific indications of potential trouble and can circumvent many problems. Pertinent aspects of stone production are reviewed in Appendix B.